Influence of Containment on the Growth of Silicon-Germanium (ICESAGE): A Materials Science Investigation

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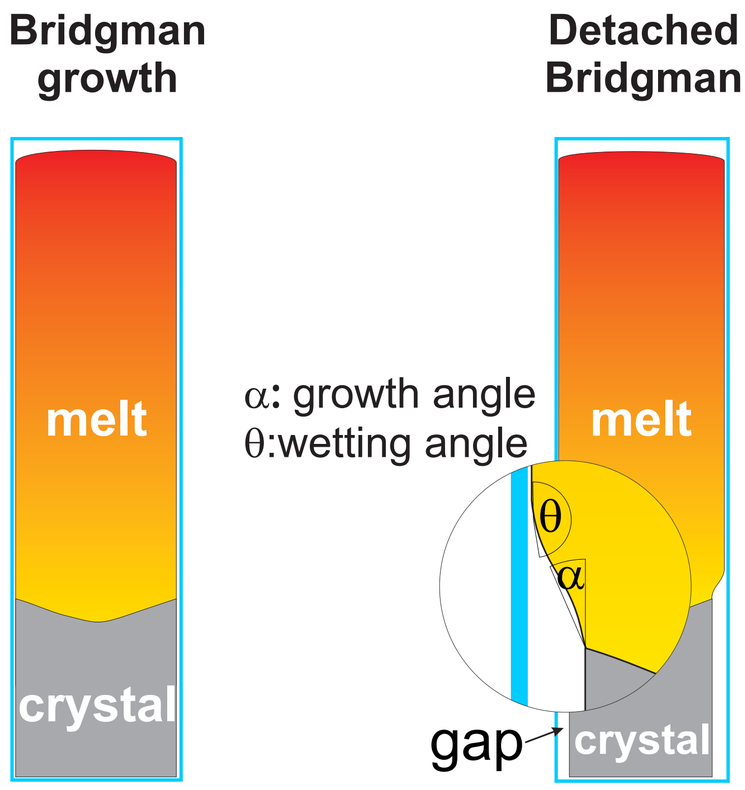
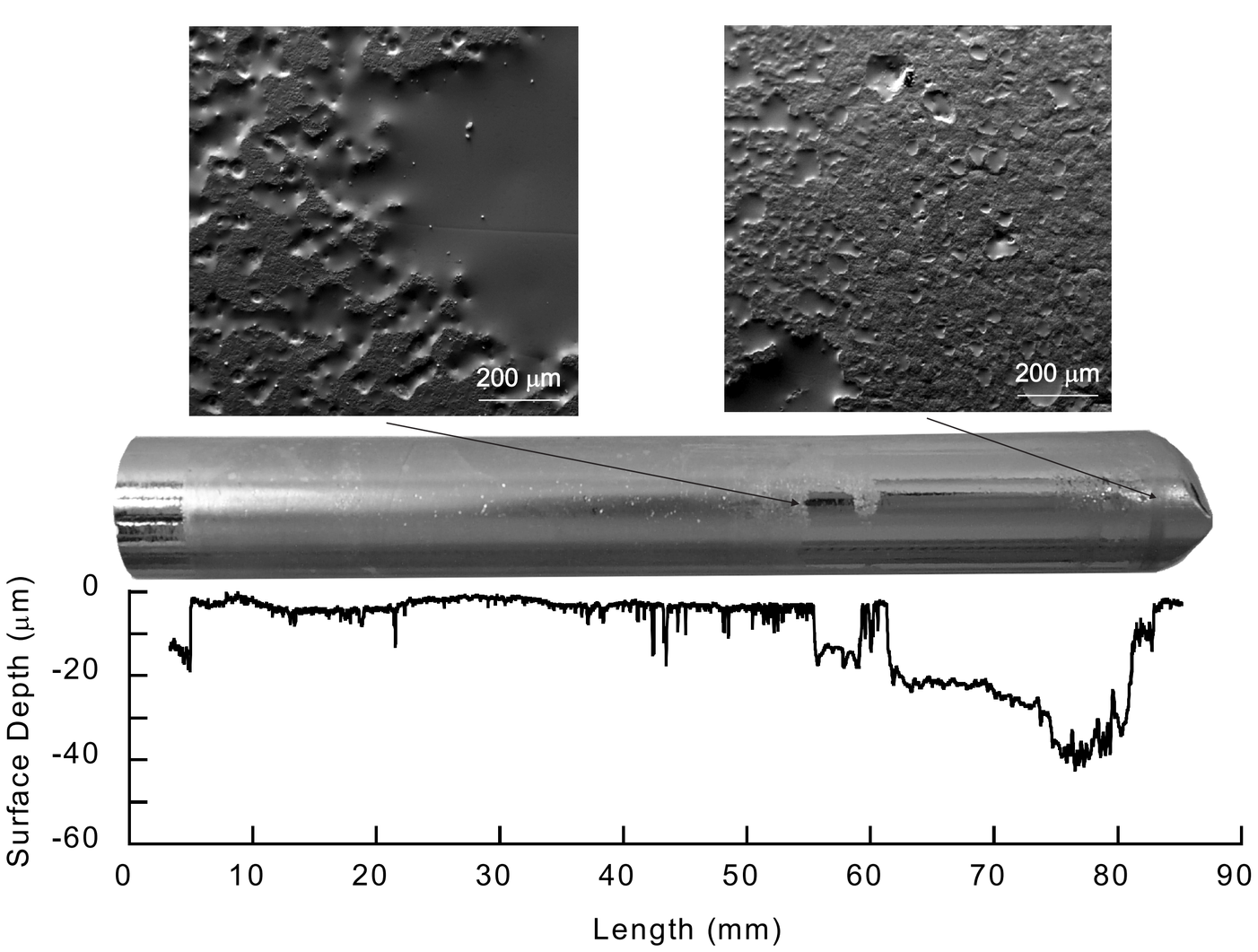
Abstract

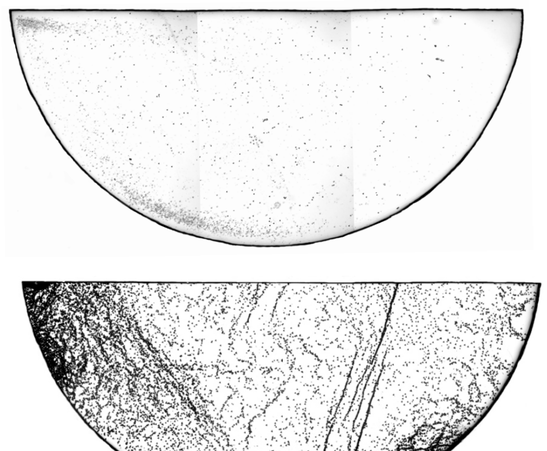
A series of $Ge_{1-x}Si_x$ crystal growth experiments are planned to be conducted in the Low Gradient Furnace (LGF) onboard the International Space Station. The primary objective of the research is to determine the influence of containment on the processing-induced defects and impurity incorporation in germanium-silicon alloy crystals. A comparison will be made between crystals grown by the normal and "detached" Bridgman methods and the ground-based float zone technique. Crystals grown without being in contact with a container have superior quality to otherwise similar crystals grown in direct contact with a container, especially with respect to impurity incorporation, formation of dislocations, and residual stress in crystals. "Detached" or "dewetted" Bridgman growth is similar to regular Bridgman growth in that most of the melt is in contact with the crucible wall, but the crystal is separated from the wall by a small gap, typically of the order of 10-100 microns. Long duration reduced gravity is essential to test the proposed theory of detached growth. Detached growth requires the establishment of a meniscus between the crystal and the ampoule wall. The existence of this meniscus depends on the ratio of the strength of gravity to capillary forces. On Earth, this ratio is large and stable detached growth can only be obtained over limited conditions. Crystals grown detached on the ground exhibited superior structural quality as evidenced by measurements of etch pit density, synchrotron white beam X-ray topography and double axis X-ray diffraction.





The left-hand secondary electron image is an expanded view of the transition between attached and detached regions. The right-hand image is an expanded view of a completely attached region. The y-axis of the plot is the depth of the detachment. The x-axis dimensions of the profilometer measurements also correspond to the dimensions of the macroscopic picture.

EPD Measurements



Detached grown crystal (UMC3)

Attached grown crystal (UMC6)

Etch-pit density measurements

D-shaped (111)-oriented radial wafers were cut perpendicular to the growth direction. They were polished and then etched with the Billig etchant (12g KOH and 8g $K_3[Fe(CN)_6]$ dissolved in 100 ml H_2O at approximately 85 C). Etch pits were counted in selected micrograph spots and then the average was computed.

Flight Experiments

- A series of $Ge_{1-x}Si_x$ samples will be processed in the Low Gradient Furnace (LGF) in the Materials Science Research Rack (MSRR) on the ISS.
- The samples are currently scheduled to be launched to the ISS on a SpaceX flight in 2015.
- The experiments will vary parameters that are key to a better understanding of the theory of detached growth: pressure differential across the meniscus, contact angle, growth angle, and Bond number (ratio of capillary and gravitational forces).
- The samples will be compared to identically processed samples on Earth.